EXPERIMENTAL REVIEW ON PENTAQUARKS

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Abstract

The experimental evidence for pentaquarks is reviewed and compared with the experiments that do not see any sign of pentaquarks.

1 Observation of pentaquarks

Until recently, all existing baryons could be interpreted as bound states of three quarks. Observations of a pentaquark state Θ^+ in nK^+ [1] and pK^0 [2] modes created a lot of excitement. The corresponding invariant mass distributions obtained by the LEPS and DIANA collaborations are shown in Fig. 1 , 2.

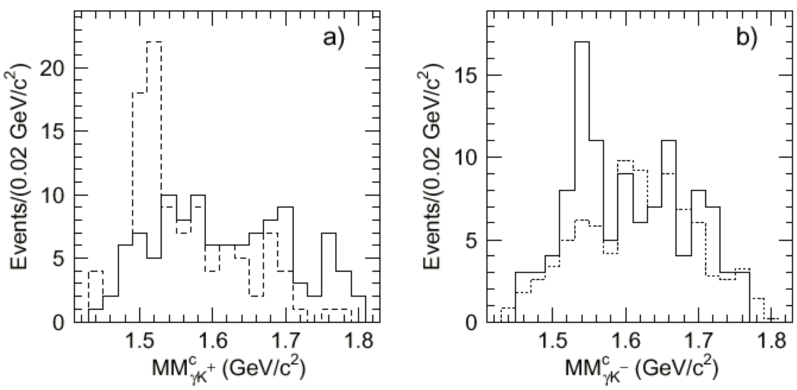

Figure 1: *Missing mass spectra for the γK^+ (left) and γK^- (right) for the reaction $\gamma C \to K^+K^-X$* [1]*. The dashed (solid) histogram shows events with (without) additional detected proton. The $\Lambda(1520)$ signal is seen on the left and evidence for Θ^+ is seen on the right.*

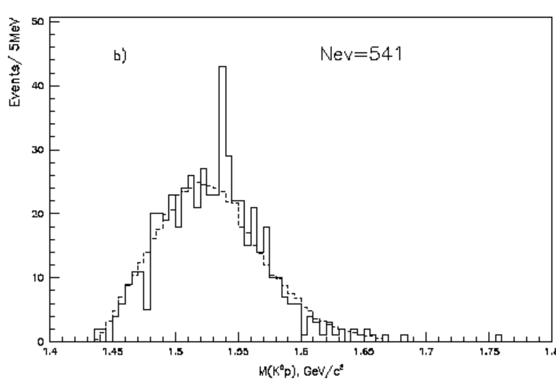

Figure 2: *Invariant mass of pK^0 in the reaction $K^+Xe \to pK_SX$* [2]*. The dashed histogram is the expected background.*

The minimal quark content of the Θ^+ is $uudd\bar{s}$. Thus for the first time unambiguous evidence was obtained for hadrons with an additional quark-

antiquark pair.

Analysis of the DIANA data demonstrates that the width of the Θ^+ is very small $\Gamma = 0.9 \pm 0.3$ MeV [3]. A similar small width was obtained from the analysis of the K^+d cross section [4) – 8)]. Such a narrow width is extremely unusual for hadronic decays and requires reassessment of our understanding of quark dynamics. Properties of the Θ^+ were in the excellent agreement with the theoretical predictions [9] based on the chiral quark soliton model. This paper motivated both experimental searches although later on the accuracy of these predictions was questioned [10]. In the quark soliton model the Θ^+ belongs to an antidecuplet of baryons (see Fig. 3). Octet, decuplet, 27-plet, and 35-plet of pentaquarks are also expected.

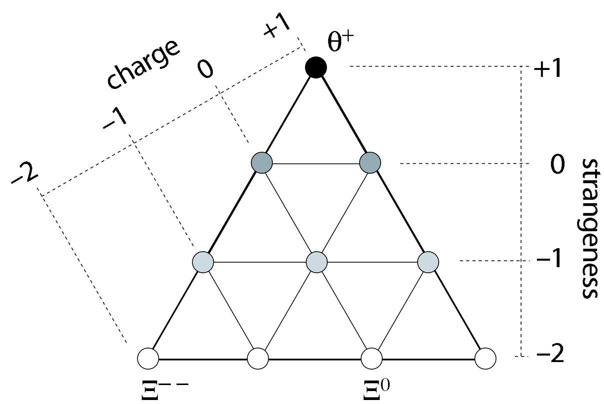

Figure 3: *The predicted anti-decuplet [9] of pentaquark baryons. Experimental evidence for three indicated particles has been presented.*

Many experiments promptly confirmed the existence of the Θ^+ [11) – 24)] in different processes: photoproduction, deep inelastic scattering, hadroproduction, and neutrino interactions. Table 1 shows properties of the observed peaks.

There is some spread in the mass values obtained by different experiments. In particular masses in the pK_S final state are lower than in the nK^+ one. The accuracy of the mass determination is not high in most of the experiments and therefore the disagreement is not very serious statistically. However the DIANA and ZEUS measurements are quite precise and contradict each other by more than 4 sigma. Several experiments observe finite width of the Θ^+ that is much larger than 1 MeV. However, the accuracy is again not high and within 3 sigma all width measurements are consistent with the instrumental resolution.

Table 1: *Experiments with evidence for the Θ^+ baryon.*

Reference	Group	Reaction	Mass (MeV)	Width (MeV)
1)	LEPS(1)	$\gamma C \to K^+K^-X$	1540 ± 10	< 25
2)	DIANA	$K^+Xe \to K^0pX$	1539 ± 2	< 9
11)	CLAS(d)	$\gamma d \to K^+K^-p(n)$	1542 ± 5	< 21
12)	SAPHIR	$\gamma d \to K^+\overline{K^0}(n)$	1540 ± 6	< 25
13)	νBC	$\nu A \to K^0_s pX$	1533 ± 5	< 20
14)	CLAS	$\gamma p \to \pi^+K^+K^-(n)$	1555 ± 10	< 26
15)	HERMES	$e^+d \to K^0_S pX$	1526 ± 3	13 ± 9
16)	ZEUS	$e^+p \to K^0_S pX$	1522 ± 3	8 ± 4
17)	COSY-TOF	$pp \to K^0p\Sigma^+$	1530 ± 5	< 18
18)	SVD	$pA \to K^0_S pX$	1526 ± 5	< 24
19)	LEPS(2)	$\gamma d \to K^+K^-X$	~ 1530	
20)	$\nu BC2$	$\nu A \to K^0_s pX$	1532 ± 2	< 12
21)	NOMAD	$\nu A \to K^0_s pX$	1529 ± 3	< 9
22)	JINR	$p(C_3H_8) \to K^0_s pX$	1545 ± 12	16 ± 4
23)	JINR(2)	$CC \to K^0_s pX$	1532 ± 6	< 26
24)	LPI	$np \to npK^+K^-$	1541 ± 5	< 11

The spread in mass and width may indicate that some experiments observe not a signal but a statistical fluctuation.

If the penaquark interpretation of observed peaks is correct one expects many other exotic (or cripto exotic) baryons belonging to the same antidecuplet or other multiplets. Indeed several experiments observe additional peaks in the vicinity of the Θ^+ mass [20, 22, 24]. For example 3 peaks with the estimated statistical significance of 7.1, 5.0, and 4.5 sigma are seen in neutrino interactions [20].

The NA49 collaboration claims an observation of a double strange pentaquark [25]. Two observed narrow resonances $\Xi^{--}_{\overline{10}}$ and $\Xi^{0}_{\overline{10}}$ (see Fig. 4) fit naturally into the same antidecuplet as the Θ^+ (see Fig. 3).

An evidence for an anti-charmed pentaquark was obtained by the H1 collaboration [26] (see Fig. 5).

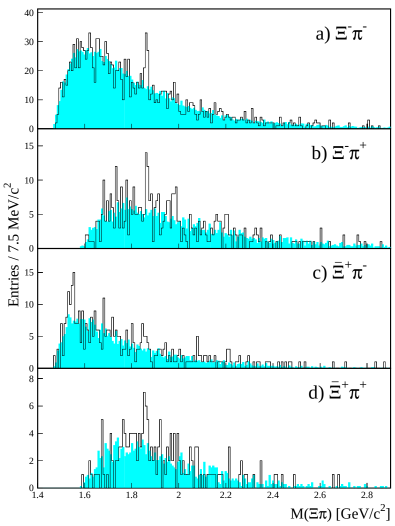

Figure 4: *Invariant mass spectra for* $\Xi^-\pi^-$ *(a),*$\Xi^-\pi^+$ *(b),*$\overline{\Xi}^+\pi^-$ *(c), and* $\overline{\Xi}^+\pi^+$ *(d) in the NA49 experiment. The shaded histograms are the normalized mixed-event backgrounds.*

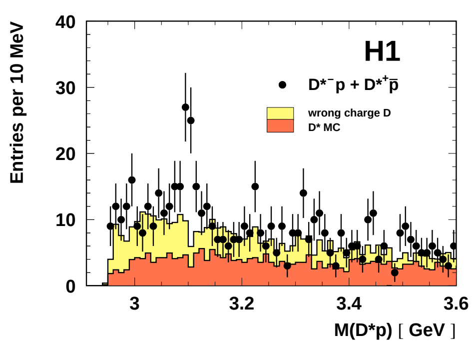

Figure 5: *Invariant mass distribution of* $D^{*-}p$ *and* $D^{*+}\overline{p}$ *combinations in the H1 experiment. Two background components are shown as the shaded histograms.*

2 Reliability of pentaquark observations

The evidence for pentaquarks was criticized by several authors (for a review see [27]). They considered kinematic reflections, ghost tracks and arbitrary selection criteria as possible explanations for the observed peaks. The first

two worries were shown to be not important at least in some experiments (for a review see [28]). The last point is especially serious since statistical significance of the positive experiments is not high and thus they are vulnerable to a psychological bias. This problem is illustrated by the JINR analysis [22] in which authors without any reason discard the momentum range where they do not see the signal . The ZUES collaboration does not see the signal in data with $Q^2 < 20$ GeV^2. Their justification for discarding these data is also not too convincing. There are other examples of experiments with not well justified cuts. On the other hand there are experiments (for example DIANA) in which event selection criteria have high efficiency and reasonably justified.

The statistical significance of peaks is overestimated in all experiments since the shape of the background is not known. This looks obvious if one removes the fit curves and plot the data points with error bars (see Fig. 6 taken from [27]).

Nevertheless the number of experiments is large and the combined significance is high if we disregard for a moment the spread in the peak position and width. So one can not prove that all observed peaks are fakes or statistical fluctuations. Only high statistics experiments can confirm or disprove the claim for pentaquarks.

3 Non-observation experiments

Experiments which do not observe pentaquarks are shown in Table 2. Many of them are high statistics experiments which observe by far larger number of conventional resonances than the experiments which observe pentaquarks, and have much better mass resolution. The first significant negative result was published by the HERA-B collaboration [33]. HERA-B does not see any evidence for the Θ^+ but observes a clear $\Lambda(1520)$ and $\overline{\Lambda}(1520)$ signals of about 2 thousand events. HERA-B obtains an upper limit on the ratio of production cross sections for the Θ^+ and $\Lambda(1520)$ of $R_{\Lambda^*} < 2.7\%$ at the 95% CL for $M_{\Theta^+} = 1530$ MeV. In the whole range of reported Θ^+ masses from 1522 MeV to 1555 MeV the limit varies up to 16%.

The ratio of the Θ^+ and $\Lambda(1520)$ production cross sections R_{Λ^*} is often used for the comparison of different experiments since $\Lambda(1520)$ is narrow and easily reconstructed, it has a mass similar to the Θ^+ mass and one can draw similar diagrams for $\Lambda(1520)$ and Θ^+ production by exchanging an $\overline{K}$ meson into a K meson. The existence of similar diagrams unfortunately does not prove that production mechanisms for Θ^+ and $\Lambda(1520)$ are similar. The ratio R_{Λ^*} is of the order of unity in several experiments which observe the Θ^+ and less than a few percent in many experiments which do not see Θ^+ (see Table 2).

In order to resolve this discrepancy many authors assume that the Θ^+ production drops very fast with energy and is heavily suppressed in e^+e^- an-

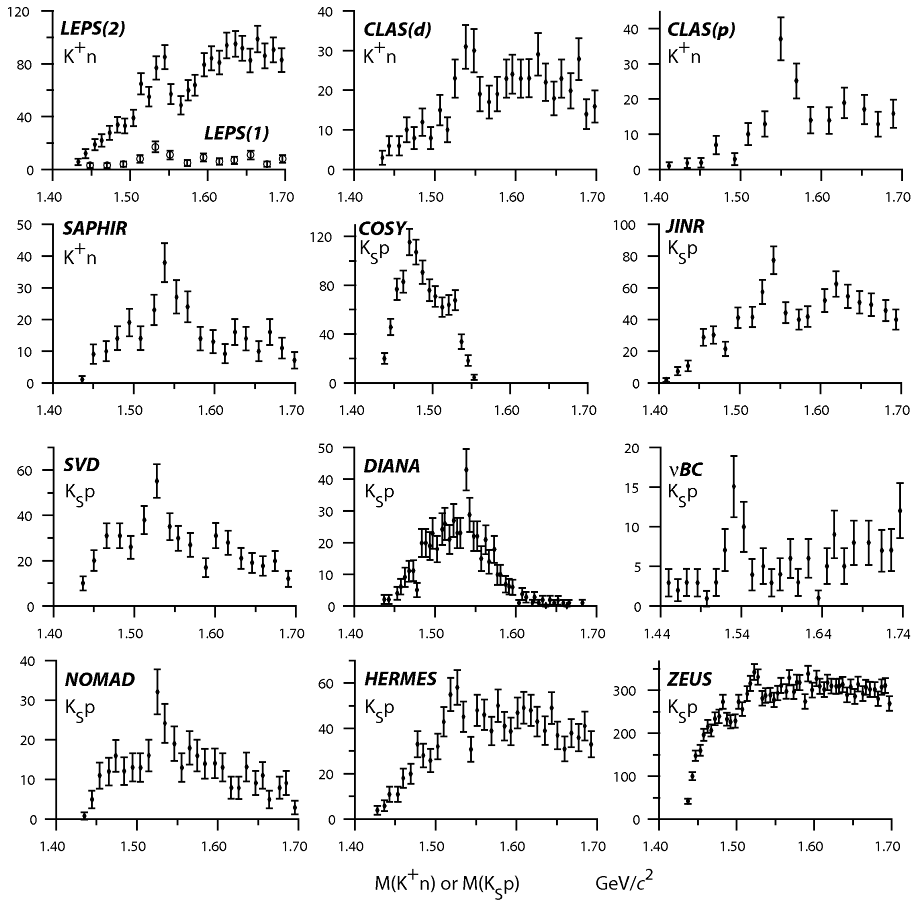

Figure 6: *Mass spectra of nK^+ and pK_S pairs in the experiments which provide evidence for the Θ^+.*

nihilation. A model exists in which the Θ^+ production cross section is strongly suppressed at high energies in the fragmentation region [44]. It is not clear how reliable this model is. In any case it is not applicable for the central production for example in the HERA-B experiment where some models predict the Θ^+ yield much higher than the experimental limits [45].

However, the Θ^+ production mechanism is not known and therefore it is important to have a high statistics experiment at low energies where most evidence for pentaquarks comes from. This goal was achieved by the BELLE collaboration which analyzed interactions of low momentum particles produced

Table 2: *Experiments with non-observation of the* Θ^+ *baryon.*

Reference	Group	Reaction	Limit
29)	BES	$e^+e^- \to J/\Psi \to \bar{\Theta}\Theta$	$< 1.1 \times 10^{-5}$ B.R.
30)	BaBar	$e^+e^- \to \Upsilon(4S) \to pK^0X$	$< 1.0 \times 10^{-4}$ B.R.
31)	Belle	$e^+e^- \to B^0\bar{B}^0 \to p\bar{p}K^0X$	$< 2.3 \times 10^{-7}$ B.R.
33)	HERA-B	$pA \to K^0_S pX$	$< 0.02 \times \Lambda^*$
34)	SPHINX	$pC \to \Theta^+X$	$< 0.1 \times \Lambda^*$
35)	HyperCP	$\pi, K, pCu \to K^0_S pX$	$< 0.3\%$ K^0p
36)	CDF	$p\bar{p} \to K^0_S pX$	$< 0.03 \times \Lambda^*$
37)	FOCUS	$\gamma BeO \to K^0_S pX$	$< 0.02 \times \Sigma^*$
38)	Belle	$\pi, K, pA \to K^0_s pX$	$< 0.02 \times \Lambda^*$
39)	PHENIX	$Au + Au \to K^-\bar{n}X$	(not given)
32)	ALEPH	$e^+e^- \to K^0_s pX$	$< 0.07 \times \Lambda^*$
40)	COMPASS	$\mu^+A \to K^0_s pX$	–
41)	DELPHI	$e^+e^- \to K^0_s pX$	$< 0.5 \times \Lambda^*$
42)	E690	$pp \to K^0_s pX$	$< 0.005 \times \Lambda^*$
43)	LASS	$K^+p \to K^+n\pi^+$	–
41)	L3	$\gamma\gamma \to K^0_s pX$	$< 0.1 \times \Lambda$

in e^+e^- interactions with the detector material. We will discuss this experiment after reviewing the situation with the anti-charmed and doubly strange pentaquarks.

4 The anti-charmed pentaquark.

The anti-charmed pentaquark was observed in the pD^{*-} and $\overline{p}D^{*+}$ channels by the H1 collaboration both in DIS and photo production [26]. After many experimental checks H1 concludes that the signal is real and self consistent. Still the signal has very unusual properties. The Θ^0_c measured width of (12 ± 3) MeV is consistent with the experimental resolution of (7 ± 2) MeV. So its intrinsic width is very small although its mass is 151 MeV above the pD^{*-} threshold and 292 MeV above pD^- threshold. Its decay into pD^{*-} is clearly visible although naively one would expect much larger branching fraction for the pD^- channel where energy release is twice larger. Finally it is produced with an enormous cross section. About 1.5% of all charged D* mesons are coming from decays of this new particle! These properties are very surprising

but we can not a priory exclude such a possibility.

However, the ZEUS experiment which works at the same electron-proton collider HERA does not see Θ_c^0 and gives an upper limit of 0.23% at the 95% CL on the fraction of charged D^* coming from Θ_c^0 decays [46]. We denote this fraction $R_{\Theta_c^0/D^*}$. For DIS events with $Q^2 > 1$ GeV^2 the upper limit is 0.35% at the 95% CL. This is a clear contradiction with the H1 result. We are not aware of any convincing explanation of this discrepancy. One can try to explain the difference using following arguments. ZEUS detects more soft D^* than H1. If one assumes that pentaquarks are produced with high momenta only, than D^* mesons from their decays should be also energetic. In this case soft D^* that are more efficiently detected by ZEUS should not be used in the comparison with H1. However such an assumption does not resolve the discrepancy since ZEUS does not see the signal also in the kinematic range very similar to the H1 one.

The CDF collaboration also does not see any sign of Θ_c^0 [36]. CDF has two orders of magnitude more reconstructed D^* mesons. They reconstruct 6247 ± 1711 $D_2^{*0} \to D^{*+}\pi^-$ and 3724 ± 899 $D_1^0 \to D^{*+}\pi^-$ decays which have the event topology very similar to Θ_c^0. Majority of charm particles at HERA and Tevatron are produced in the fragmentation process. It is impossible to reconcile the results of the two experiments if Θ_c^0 is produced in the fragmentation process as well. No other mechanism was proposed so far. There are also upper limits on Θ_c^0 production in e^+e^- collisions by ALEPH [32] and in photo production by FOCUS [37].

We conclude that the evidence for Θ_c^0 is by far weaker than the evidence against it.

5 Doubly strange pentaquark.

The NA49 claim for the observation of the doubly strange pentaquark was not supported by several experiments which tried to find it. HERA-B has 8 times more Ξ^- hyperons and slightly better mass resolution. There is no $\Xi(1862)$ signal in the $\Xi^-\pi^-$ or $\Xi^-\pi^+$ mass distributions (see Fig. 7) while there is a clear $\Xi(1530)^0$ peak with about 1000 events (including charge conjugate combinations). HERA-B sets an upper limit of $4\%/B(\Xi(1862)^{--} \to \Xi^-\pi^-)$ at the 95%CL on the ratio of production cross section for $\Xi(1862)^{--}$ and $\Xi(1530)^0$. We denote this ratio $R_{\Xi(1862)/\Xi(1530)}$. $R_{\Xi(1862)/\Xi(1530)}$ is about $18\%/B(\Xi(1862)^{--} \to \Xi^-\pi^-)$ in the NA49 experiment [33, 47]. The center of mass energy in HERA-B is about 2 times larger than in NA49. However the arguments about a very fast drop of the pentaquark production cross section in the fragmentation region [44] do not apply to the central production where the signal is observed by NA49 [25, 48] and where it is searched for at

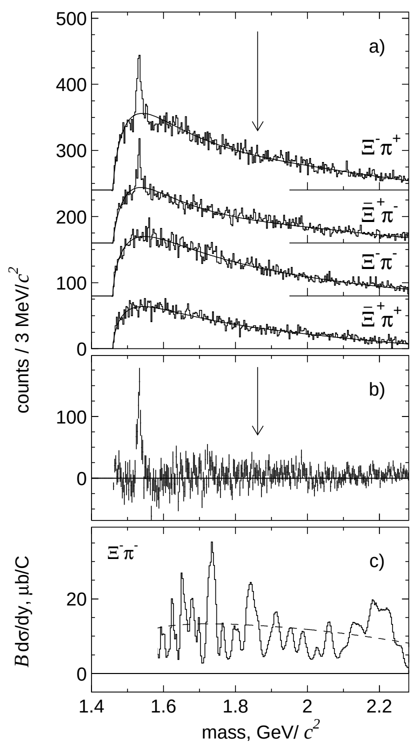

Figure 7: *The $\Xi\pi$ invariant mass spectra for $p + C$ collisions in the HERA-B experiment (a); sum of all four $\Xi\pi$ spectra with the background subtracted (b); upper limit at 95%CL for mid-rapidity (c) .*

HERA-B. The E690 experiment has even smaller limit on the $R_{\Xi(1862)/\Xi(1530}$ of $0.2\%/B(\Xi(1862)^{--} \rightarrow \Xi^-\pi^-)$ at the 95% CL [42]. E690 studies proton - proton interactions at 800 GeV i.e. the same process as NA49 but at the twice larger CM energy. The WA89 experiment has about 300 times larger number of Ξ^- hyperons but does not observe $\Xi(1860)$ [49]. However this experiment uses a Σ^- beam and a straightforward comparison is not possible. The ALEPH, BaBar, CDF, COMPASS, FOCUS and ZEUS experiments also do not see $\Xi(1862)$ in a variety of initial processes [32, 30, 36, 40, 37, 46].

We conclude that the evidence for $\Xi(1862)$ is by far weaker than the evidence against it.

6 The Belle experiment

As discussed above many high statistics experiments do not see the Θ^+ and set stringent limits on its production cross section in different processes. It was argued, however, that the Θ^+ production can be suppressed at high energies or in specific processes like e^+e^- annihilation. Therefore Belle decided to study interactions of low momentum particles produced in e^+e^- interactions with the detector material. This allows to achieve production conditions similar to the experiments which observe the Θ^+ . For example the most probable kaon momentum is only 0.6 GeV (see Fig. 8). The Belle kaon momentum spectrum has a large overlap with the DIANA spectrum [2].

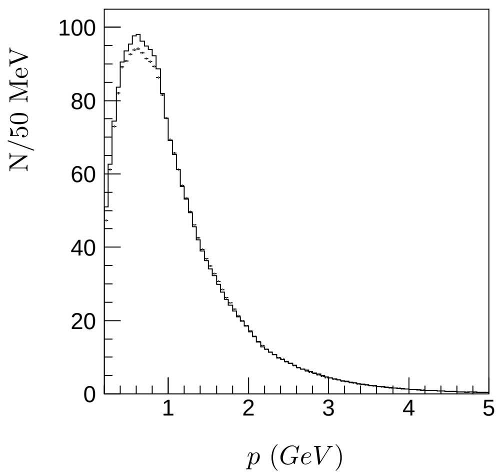

Figure 8: *Momentum spectra of K^+ (solid histogram) and K^- (dashed histogram) in the Belle experiment.*

The analysis is performed by selecting pK^- and pK_S secondary vertices. The protons and kaons are required not to originate from the region around the run-averaged interaction point. The proton and kaon candidate are combined and the pK vertex is fitted. The xy distribution of the secondary pK^- vertices is shown in Fig. 9 for the barrel part (left) and for the endcap part (right) of the detector. The double wall beam pipe, three layers of SVD, the SVD cover and the two support cylinders of the CDC are clearly visible. The xy distribution for secondary pK_S vertices is similar.

The mass spectra for pK^- and pK_S secondary vertices are shown in Fig. 10. No significant structures are observed in the $M(pK_S)$ spectrum, while in the $M(pK^-)$ spectrum a $\Lambda(1520)$ signal is clearly visible.

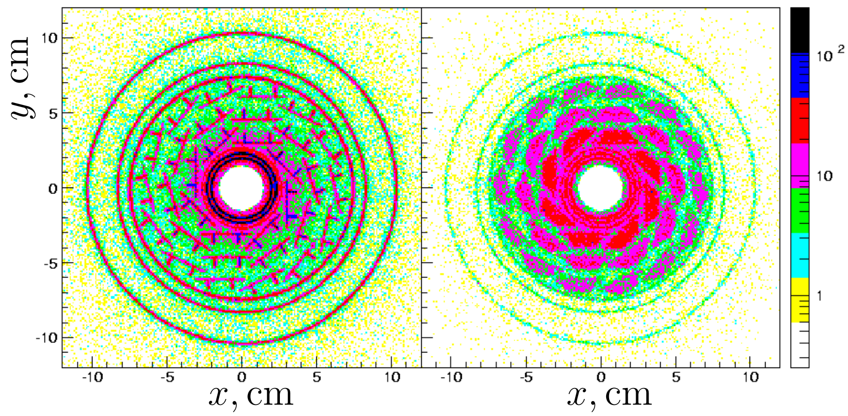

Figure 9: *The xy distribution of secondary pK^- vertices for the barrel (left) and endcap (right) parts of the Belle detector.*

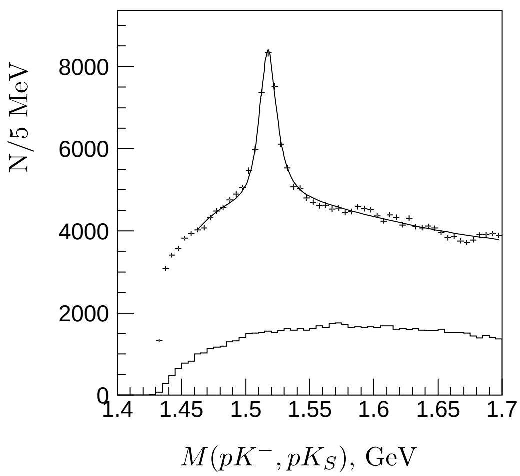

Figure 10: *Mass spectra of pK^- (points with error bars) and pK_S (histogram) secondary pairs in the Belle experiment.*

The $\Lambda(1520)$ yield is 15.5 thousand events. The $\Lambda(1520)$ momentum spectrum is relatively energetic (see Fig. 11). $\Lambda(1520)$ produced in a formation channel should be contained mainly in the first bin of the histogram even in the presence of the Fermi motion. Therefore most of $\Lambda(1520)$ are produced in

the production channel.

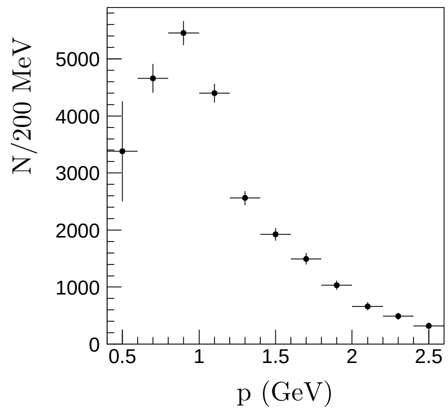

Figure 11: $\Lambda(1520)$ *momentum spectrum in the Belle experiment.*

The upper limit for the narrow Θ^+ yield is 94 events at the 90% CL for $M_{\Theta^+} = 1540$ MeV. This leads for the upper limit of 2% at the 90%CL on the ratio of Θ^+ and $\Lambda(1520)$ production cross sections. For other reported Θ^+ masses the limit is even smaller.

Projectiles are not reconstructed in the Belle approach. Therefore the Θ^+ and $\Lambda(1520)$ can be produced by any particle originating from the e^+e^- annihilation: $K^{\pm}$, $\pi^{\pm}$, K_S^0, K_L^0, p, Λ, etc. Belle shows that $\Lambda(1520)$ are seldom accompanied by K^+ mesons from the same vertex. This means that $\Lambda(1520)$ are produced mainly by particles with negative strangeness. The fraction of energetic Λ hyperons in e^+e^- annihilation is too small to dominate $\Lambda(1520)$ production.

The Belle limit is much smaller than the results reported by many experiments which observe the Θ^+. For example it is two orders of magnitude smaller than the value reported by the HERMES Collaboration [15]. The Θ^+ and $\Lambda(1520)$ are produced in inclusive photoproduction at HERMES. Photons produce hadrons dominantly via (virtual) pions or Kaons. Therefore the production conditions are quite similar in the two experiments. We do not know any physical explanation for the huge difference between the Belle and HERMES results.

The expected number of reconstructed Θ^+ in the formation reaction $K^+n \to pK_S^0$ can be estimated knowing the Θ^+ width, the number of K^+ mesons with appropriate momentum, amount of material and the reconstruction efficiency. The Θ^+ width was estimated using the DIANA data to be 0.9 ± 0.3 MeV [3]. Using this value of the Θ^+ width we estimate the number of

expected Θ^+ events at Belle to be comparable with their upper limit. If so the Belle result disagrees with the DIANA observation. However we should wait for a quantitative statement from the Belle Collaboration.

A comparison of the Belle upper limit on R_{Λ^*} with the exclusive photoproduction experiments is not simple. However, it is very strange to have about two orders of magnitude difference in R_{Λ^*} since the Belle kaon (and pion) momentum spectrum is quite soft and comparable with the momentum spectrum of virtual kaons (or pions) in the low energy photoproduction experiments.

7 Conclusions.

The NA49 claim for the observation of $\Xi(1862)$ pentaquarks is hard to reconcile with the results of many experiments which have up to 300 times larger statistics of usual Ξ^- and $\Xi(1530)$ hyperons and a better mass resolution. In particular E690 investigated the same production process at about twice larger CM energy and obtained hundred times lower limit on the ratio of $\Xi(1862)$ and $\Xi(1530)$ production cross sections.

The H1 claim for the anti-charmed pentaquark contradicts the ZEUS study made at almost identical conditions. CDF sets a very stringent limit on the Θ_c^0 yield although they observed 178 times more D^* than H1. CDF reconstructed also about 10 thousand $D_2^{*0} \to D^{*+}\pi^-$ and $D_1^0 \to D^{*+}\pi^-$ decays (including charge conjugate states). These decays are very similar in kinematics and efficiency to $\Theta_c^0 \to pD^{*-}$ decays (the H1 signal is observed mainly with energetic protons for which the particle identification does not play an important role). Three other experiments do not see any sign of the Θ_c^0 in different production processes [32, 31, 37]. It is hard to reconcile the H1 claim with this overwhelming negative evidence.

The claims for observation of the Θ^+ in inclusive production at medium and high energies are not supported by many high statistics experiments which reconstruct by far larger number of ordinary hyperons with negative strangeness. Even if one assumes that the Θ^+ production is strongly suppressed at high energies there is still a contradiction between several of these results with the Belle upper limit obtained with low momentum kaons.

However, even if some claims for the Θ^+ observation are wrong it does not mean that all observations are wrong. The DIANA and exclusive photoproduction experiments are not in contradiction with the high energy experiments if one assumes that the Θ^+ production drops very fast with the energy. There is a qualitative disagreement of these experiments with the Belle data. However here we should wait for the quantitative analysis of the Belle data. Results of high statistics exclusive photoproduction experiments are expected very soon. We hope that the situation with the pentaquark existence will be clarified already this year.

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References

1. T. Nakano *et al.*, (LEPS), Phys. Rev. Lett. **91**:012002 (2003); hep-ex/0301020.

2. V.V. Barmin *et al.*, (DIANA), Phys. Atom. Nuclei **66**, 1715 (2003); hep-ex/0304040.

3. R.N. Cahn and G.H. Trilling, Phys. Rev. **D69**, 011501 (2004).

4. S. Nussinov, hep-ph/0307357.

5. R.A. Arndt *et al.*, Phys. Rev. **C68**, 042201 (2003); Erratum **C69**, 019901 (2004).

6. J. Haidenbauer and G. Krein, Phys. Rev. **C68**, 052201 (2003).

7. A. Sibirtsev *et al.*, Phys. Lett. **B599**, 230 (2004).

8. W.R. Gibbs, Phys. Rev. **C70**, 045208 (2004).

9. D. Diakonov, V. Petrov and M. Polyakov, Z. Phys. A **359**, 305 (1997).

10. J. Ellis, M. Karliner and M. Praszalowicz, JHEP **0405**, 2 (2004); hep-ph/0401127.

11. S. Stepanyan *et al.*, (CLAS), Phys. Rev. Lett. **91**:25001 (2003); hep-ex/0307018.

12. J. Barth *et al.*, (SAPHIR), Phys. Lett. **B572**, 127 (2003); hep-ex/0307083.

13. A.E. Asratyan, A.G. Dolgolenko and M.A. Kubantsev, Phys. Atom. Nucl. **67**, 682 (2004); hep-ex/0309042.

14. V. Kubarovsky *et al.*, (CLAS), Phys. Rev. Lett. **92**:032001 (2004); hep-ex/0311046.

15. A. Airapetian *et al.*, (HERMES), Phys. Lett. **B585** (2004) 213; hep-ex/0312044.

16. The ZEUS collaboration, Phys. Lett. **B591** (2004) 7; hep-ex/0403051.

17. M. Abdel-Barv, *et al.*, (COSY-TOF), Phys. Lett. **B595**, 127 (2004); hep-ex/0403011.

18. A. Aleev *et al.*, (SVD), submitted to Yad. Fiz.; hep-ex/0401024.

19. T. Nakano, QNP2004 Conference, www.qnp2004.org.

20. A. Asratyan, A. Dolgolenko and M. Kubantsev, Nucl. Phys. B (Proc.Suppl.) **142** 79 (2005).

21. L. Camilleri, Presented at Neutrino 2004, Paris, neutrino2004.in2p3.fr.

22. P. Aslanyan *et al.*, , hep-ex/0403044.

23. R.Togoo *et al.*, , Proc. Mongolian Acad. Sci. 4(2003)2.

24. Yu.Troyan *et al.*, , hep-ex/0404003.

25. C. Alt *et al.*, (NA49), Phys. Rev. Lett. **92**, 042003 (2004); hep-ex/0310014.

26. A. Aktas *et al.*, , Phys. Lett. B **588**, 17 (2004); hep-ex/0403017.

27. A.Dzierba, C.Mayer, A.Szczepanek, hep-ex/0412077.

28. K. Hicks *et al.*, , submitted to Phys. Rev. D; hep-ph/0411265.

29. J.Z. Bai *et al.*, (BES), Phys. Rev. D **70**:012004 (2004); hep-ex/0402012.

30. The BaBar Collaboration, hep-ex/0408064.

31. The Belle Collaboration, hep-ex/0409010.

32. S.R. Armstrong, hep-ex/0410080; S. Schael *et al.*, (ALEPH), Phys. Lett. B **599**, 1 (2004).

33. I. Abt *et al.*, (HERA-B), Phys. Rev. Lett. **93**:212003 (2003); hep-ex/0408048.

34. Yu.M. Antipov *et al.*, (SPHINX), Eur. Phys. J. **A21**, 455 (2004); hep-ex/0407026.

35. M.J. Longo *et al.*, (HyperCP), Phys. Rev. D **70**:111101 (2004); hep-ex/0410027.

36. I. Gorelov *et al.*, (CDF), hep-ex/0408025;
D. Litvintsev *et al.*, (CDF), hep-ex/0410024.

37. K. Stenson *et al.*, (FOCUS), hep-ex/0412021.

38. K. Abe *et al.*, (Belle), hep-ex/0411005.

39. C. Pinkerton *et al.*, (PHENIX), J. Phys. G **30**:S1201 (2004); nucl-ex/0404001.

40. G. Brona and B. Baddek (COMPASS), 2004 www.compass.cern.ch/compass/notes/2004-5.

41. S. Armstrong, hep-ex/0410080.

42. D. Cristian *et al.*, , (E690) www.qnp2004.org.

43. J. Napolitano *et al.*, , hep-ex/0412031.

44. A.I. Titov, A. Hosaka, S. Date and Y. Ohashi, Phys. Rev. C **70**:042202 (2004).

45. F. Becattini *et al.*, , Phys.Rev. C69, 024905(2004).

46. S. Chekanov *et al.*, (ZEUS), Eur. Phys. J. **C38**, 29 (2004); hep-ex/0409033.

47. H.G. Fischer and S. Wenig, Eur. Phys. J. **C37**, 133 (2004); hep-ex/0401014.

48. D. Barna PhD Thesis, NA49 note 294 at http://na49info.cern.ch.

49. M.I. Adamovich *et al.*, (WA89), Phys. Rev. C **70**:022201 (2004); hep-ex/0405042.